Research on the Framework of Online Course Design Based on "First Principles of Instruction"

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Abstract: In the field of online courses, people are keen on the research and application of new technologies and theories, but ignore the application of traditional teaching theories and basic cognitive psychology. That deviates from the essence of learning to some extent. Nowadays, the learning environment and means are quite different from the past, but the essence of learning has not changed. Therefore, it is necessary to apply the traditional teaching theories to online courses. As an attempt to bring online courses back to the essence of learning, we suggested applying Merrill's First Principles of Instruction in the online courses, and proposed an online course design framework based on it. We have built an online course of Java programming using that framewok, and our teaching practice showed that the framework was effective in online course design and online teaching. Our research results could provide enlightenment and reference for more application of teaching theories and cognitive theories to online courses design and development in the future.

1. Introduction

With the rapid development of MOOC(Massive Open Online Courses) and SPOC(Small Private Online Courses), online courses have provided more learning opportunities and facilities for learners. People continue to pull-in various new technologies and teaching concepts into online courses to try to solve teaching problems, but ignore the impact of traditional teaching theories or cognitive psychological theories on learners. That is not enough in online teaching and learning.

Despite people's learning environment and means have changed a lot with the development of information technology nowadays, the underlying learning mechanisms of individual learners have not changed. We can see that the learning mechanism of young people is not significantly different from their parents [1]7-8. As the nature of learning and human cognitive psychology remain unchanged, the application of traditional teaching theories and cognitive psychological theories to online courses will inevitably make up for the current deficiencies and promote online teaching.

Some researchers have carried out this research. Lee Stella et al. applied Experiential-Learning Theory (ELT) and Self-Regulated Learning (SRL) Theory to "Java programming guidance" online course [2]. They developed an online learning model called "a Learner-Directed Model" besed on ELT and SRL. Their Model can provide a positive learning experience and optimal levels of learner control, however it does not provide specific learning guidance. Chen, O. et al. proposed the application of cognitive load theory in online learning curriculum design including MOOCs [3]. They indicated some instructional design principles that could be used to structure online learning based on cognitive load theory but not the specific design method. Benilde Garcı´a-Cabrero et al. designed and developed an online learning environment using Cognitive Apprenticeship Model(CAM) [4]. That online learning environment can led to significant improvement in online learning. The disadvantage of their method is that its application is limited due to the lack of enough experts. Lo C. K. et al. applied Merrill's First Principles of Instruction(FPI) to the flipped classroom of middle school mathematics [5]. They gave some guidelines of flipped classroom instruction, and their experiment shows that those guidelines have good effect. However, their guidelines are not for online courses. Klein J. and Mendenhall A. studied the application of First Principles of Instruction

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in a fast-paced project that required the creation of a large number of online modules to determine how they were implemented [6]. Their Findings reveals that project requirements, personnel, physical setting, time, designer experience, training and team meetings influence the use of the First Principles of Instruction.

Although some researchers have carried out the research work of applying teaching theories and cognitive theories to online courses and achieved preliminary results, there is still a long way to go before the effective teaching of online courses. We need to do more extensive and in-depth researches on the teaching design of online courses.

In this study, we discussed the application of First Principles of Instruction in the online courses, and proposed an online course design framework based on it. We have built an online course of Java programming using that framewok, and our teaching practice showed that the framework was effective in online course design and online teaching. Our research results could provide enlightenment and reference for more application of teaching theories and cognitive theories to online curriculum design and development in the future.

2. General problems

The basic attribute of online course is the separation of time and space between teachers and learners, which makes online course teaching very different from traditional course teaching.

From the perspective of teaching, online courses have the following characteristics:

(1) Leaners take online learning resources as the main carrier.

(2) The interaction between teachers and students is mainly non-real-time interaction and supplemented by real-time interaction.

(3) Learners often use fragmented time to learn.

(4) Teaching feedback is lagging behind.

From the perspective of development, online courses have the following characteristics:

(1) It needs professional teachers and technical developers to form a team for developing an online course.

(2) The cost of the online course is high.

(3) It is difficult to modify the course after it is running.

(4) The technology realization of experiment and practice is complex.

In order to adapt to the above characteristics of online course, the following basic problems should be considered in the design of online course:

(1) How to design online learning resources to present subject content efficiently?

(2) How to design online learning resources to carry teaching activities?

(3) How to effectively realize non-real-time interaction of courses?

(4) How to guide learners to build systematic knowledge system from fragmented learning?

(5) How to collect teaching feedback to improve teaching?

(6) How to design curriculum structure to facilitate the development and continuous improvement of online course?

(7) How to achieve a balance between the objectives of teaching and the technical realization?

3. Fundamental theories

Followed by years of exploration and practice, people have summed up many effective teaching theories. Here we summarize these theories relevant to our study.

3.1 E3 teaching

The conception of e^3 teaching was put forward by Merrill [1]. The e^3 teaching refers to the effective, efficient, and engaging teaching. Merrill pointed out that teaching is a well-organized learning environment to help students master specific knowledge and skills, and the purpose of teaching is to promote students' learning. The so-called “promotion” refers to that compared with the incidental learning without intervention, the learning after receiving the teaching will have

better effect, higher efficiency and greater participation. If we look at it from the perspective of learners, teaching should let learners invest as little time, energy and material resources as possible to achieve the best learning effect.

3.2 First principles of instruction

The First Principles of Instruction [1] takes the problem-centered instructional strategy as the core, and decomposes the component skills in problem solving for guiding the instructional design and teaching practice. The core of First Principles of Instruction is five instruction principles, which is also called five stars instruction mode.

These five instruction principles are as follows.

▪Problem-Centered: Learning is promoted when learners acquire skill in the context of real-world problems.

▪Activation: Learning is promoted when learners activate existing knowledge and skill as a foundation for new skills.

▪Demonstration: Learning is promoted when learners observe a demonstration of the skill to be learned.

▪Application: Learning is promoted when learners apply their newly acquired skill to solve problems.

▪Integration: Learning is promoted when learners reflect on, discuss, and defend their newly acquired skill.

The core of First Principles of Instruction is to focus on problems. The teaching process is carried out in accordance with the four stages of the teaching cycle: activating the old knowledge, demonstrating the new knowledge, applying the new knowledge and integrating them. It is shown in Figure 1.

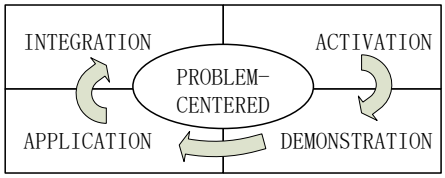

Figure 1 The Teaching Cycle of First Principles of Instruction

3.3 Efficient learning methods

From the perspective of cognitive psychology, people's learning is different from each other, and the method applicable to one person may not work for another. In addition, different learning skills may be required for different types of materials. Here are some typical efficient learning methods.

▪PQ4R: That is Preview, Question, Read, Reflect, Recite, and Review [11]5.

▪Elaborate: A process that helps transfer the material you are reading into long-term memory is elaboration-thinking about what you are reading and giving it meaning by relating it to other things that you know [12]202.

▪Organize: The goal of organizing material is to create a framework that helps relate some information to other information to make the material more meaningful and therefore strengthen encoding. Organization can be achieved by making "trees" or outlines or lists that group similar facts or principles together. Organization also helps reduce the load on your memory [12]202-203.

4. The design framework of online course based on first principles of instruction

The nature of the separation of teachers and students makes many traditional teaching methods and theories difficult to be used in online courses. For a long time, most of the teachers who teach online courses are domain experts in related disciplines. Although they are familiar with and good at the professional knowledge and skills in that field, they know little about teaching methods and theories. In many online course development teams, there are specialized experts in pedagogy or educational technology to guide the course design, but the educational experts do not know much about discipline domain knowledge. This gap makes it difficult for many useful teaching methods

and theories to be properly applied to online courses. Therefore, it is of practical significance to design a teaching framework to help discipline domain experts and educational technology experts work together to build an e^3 online course.

The First Principles of Instruction not only provides the basic principles for curriculum design, but also provides practical guidance. Therefore, taking the First Principles of Instruction as the guidance of building online course is a reasonable choice, which will help to realize e^3 teaching.

In view of the above two points, we propose an online course design framework based on First Principles of Instruction.

4.1 Online course design framework

The development of online courses is a systematic project that closely links teaching contents, activities and technology realization. In order to help teachers to complete online curriculum design better, we put forward an online curriculum design framework based on the above basic theory. The frame structure is shown in Figure 2.

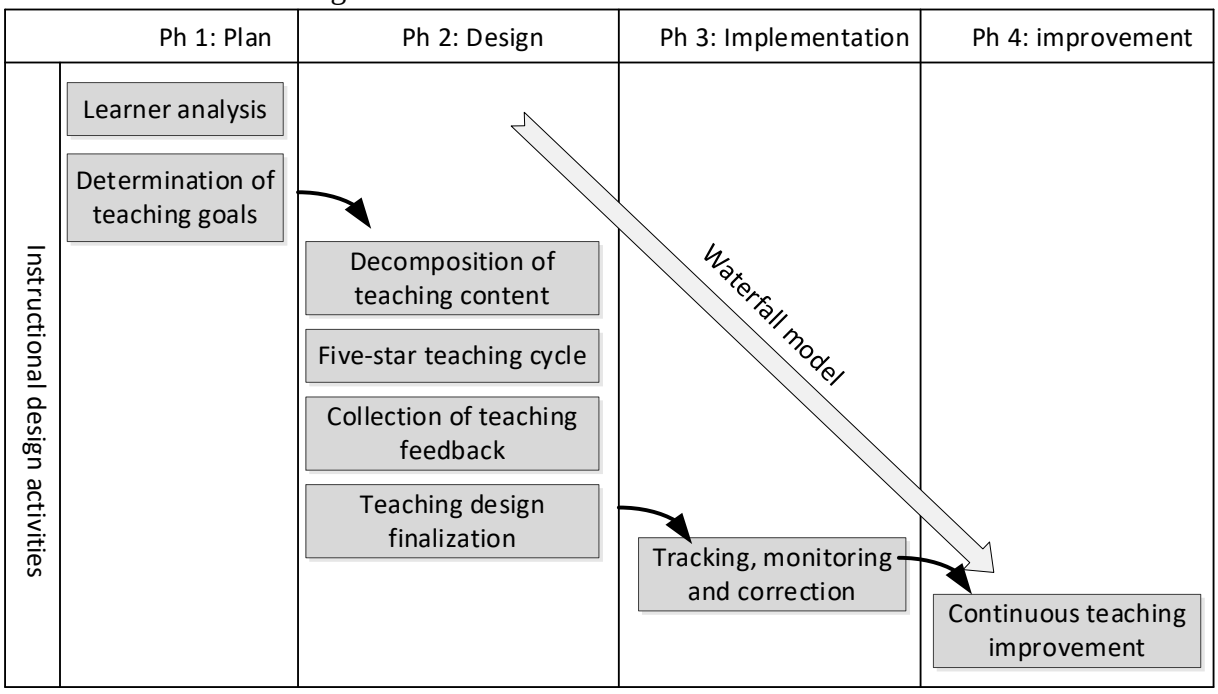

Figure 2 The Framework of Online Course Design Based on the First Principles of Instruction

We divided the teaching design activities in online course development into four stages: teaching planning stage, teaching design stage, course implementation stage and course improvement stage. The teacher completes the corresponding instructional design activities in each stage. All teaching activities form a waterfall model.

▪Learner analysis. The first step of curriculum design is learner analysis, which is the basis for the determination of teaching goals. The task of learner analysis is to investigate and analyse the basic information, knowledge and skills of learners. Basic information includes learners' gender, age, occupation, region, etc. Knowledge and skills include major, academic ability, learning basis of the course, online learning technology, possible learning period, etc. Learners analysis can be conducted by on-site questionnaire or online questionnaire, or by employing a third-party survey organization.

▪Determination of teaching goals. The task of determining teaching goals is to determine the scope and requirements of teaching. On the basis of learner analysis results, the teaching goals are determined by combining the subject knowledge and skill content. The teaching goals should be achievable, and any teaching goal that breaks away from the actual situation of learners cannot be achieved. The teaching goal should be concise, for many details of it can be determined later.

▪Decomposition of teaching content. The task of this activity is to divide the teaching content into several teaching units. Teachers should further decompose each teaching unit into a series of

teaching modules. In the process of decomposition, teachers should try to make units relatively independent, and modules are also independent. The advantages of reducing the coupling between modules are that makes the course suitable for online learners' fragmented learning and conducive to continuous improvement of the course.

▪Five-star teaching cycle. The task of the five-star teaching cycle is to design the teaching content and activities of each unit according to the five principles of the First Principles of Instruction, for example, to design the framework for activating the old knowledge, to design the problem progression and to design the coaching activities. Teachers need to apply the four stages of five-star teaching cycle to the design and development of each unit and each module.

▪Collection of teaching feedback. The purpose of this activity is to understand the actual learning situation of students, so as to facilitate the follow-up teaching improvement. Because of the non-real-time communication, it is more difficult to collect the feedback information of online teaching than traditional teaching, and it has obvious lag. In the course design, the teaching feedback function needs to be built into each unit in order to collect feedback information in time during the teaching process. We can use online questionnaire or short test to collect teaching feedback information. The design of teaching feedback function should be as simple as possible to avoid too much burden on learners.

▪Teaching design finalization. It is necessary to review the whole teaching design results and finalize the design structure. Once the teaching design is finalized, it can be handed over to the curriculum developers for development.

▪Tracking, monitoring and correction. In the process of curriculum development, there may be some deviations between the technical realization of developers and the initial ideas of teachers. Teachers need to track and monitor the development process, review whether the implementation of the developer meets the original design intent, and correct the deviation in time. Some software engineering methods, such as prototype method, incremental development method and agile development method, can be used to reduce the probability of deviation and ensure the quality of curriculum development.

▪Continuous teaching improvement. The change of learners, the development of subjects and the progress of technology require the continuous improvement of online courses in their life cycle. Teaching improvement should include the improvement of teaching contents, media forms and activities, et al.

4.2 Five-star teaching cycle

The core of the First Principles of Instruction is the teaching strategy of focusing on Problems. A problem-centered approach differs from problem-based learning or case-based learning as they are typically described in the instructional literature. A problem-centered approach is much more structured [1]26. A problem-centered approach emphasizes practical and complex problems. It can activate the old knowledge and apply the new knowledge by decomposing the complex practical problems into problem progression. However, this method is not perfect, for it is difficult to find the corresponding practical problems in some subjects. For example, some highly abstract concepts and theorems in mathematics are difficult to find practical problems. Therefore, we might as well expand the word “problem”. What we call “problem” can be a real and complex problem in life, or a problem to be solved in discipline theory. We consider that all the problems that can activate the old knowledge of learners are well problems.

The step after the design of problem progression is component skill decomposition. The First Principles of Instruction identifies five primary types of component skill: *information-about, part-of, kind-of, how-to,* and *what-happens.* This decomposition strategy is not fully applicable to science and engineering courses. For the course of science and engineering, we suggest another method, that is to divide knowledge and ability into two categories according to declarative knowledge and procedural knowledge. The knowledge involved in problem solving is limited, it is difficult to design a problem to cover all the knowledge points of the whole learning unit, and there are always some knowledge points outside the problem progression. In order to maintain the integrity of the

subject knowledge system, we need to organize all knowledge points of the unit either in order or in partial. After that, teachers should provide students with a structure to solve the problem and guide students to solve the problem. Thus, we adjust Merrill's principles to make it more suitable for online courses and named it five-star teaching cycle framework of online courses. It is shown in Table 1.

Table 1 Five-Star Teaching Cycle Framework of Online Courses

	Instructional design activities	Interaction activities
1. Problem-Centered	(1)Find a real and complex problem in life, or a problem to be solved in discipline theory.	N/A
2. Problem progression	(1)Design question progression according to questions and unit teaching content. The problem progression is required to: (a) cover as many unit knowledge points as possible; (b) transition from easy to difficult. (2)Define the purpose of the subproblem in the problem progression. The first simple questions are used to activate the old knowledge, the later questions are used to demonstrate the new knowledge, and the last relatively complex questions are used to apply the new knowledge. (3)Decompose knowledge and skills. (4)Organize the Sequence of knowledge points.	N/A
3. Activation	(1)Refine problems used to activate old knowledge. (2)Design a structured framework to activate learners' old knowledge. It requires a structured framework to: (a) activate the mental model consistent with the new knowledge to be learned; (b) be easy to understand without increasing cognitive load.	Tell, Show and Ask
4. Demonstration	(1)Refine problems used to demonstrate new knowledge. (2)Design and give the teaching content of specific knowledge points. (3)Demonstrate the framework, process and results for the demonstration problems.	Tell, Show, Ask and Guide
5. Application	(1)Design and refine the problems for application. The problem can be an extension of the demonstration problem, or a new problem designed according to the new knowledge points which learners have learned from the current unit. (2)Design a guiding structural framework for problem-solving so that students can refer to it when solving problems.	Show and Coach
6. Integration	(1)Design a structured framework to guide learners' reflection. (2)Design teaching activities to promote learners' reflection.	Show and Comment

5. Case study

We have an online course “Java programming” for students. This course is for students without Java experience. The goal of the course is to enable them to independently develop some Java programs with simple functions after a semester of study. Here we present the five-star teaching cycle design of the course.

Because there are so many prototypes in the course of “Java programming”, only the core process and some examples are described here. We take the “Java programming basics” unit of the course as an example. This unit introduces the basic knowledge and skills of Java programming, such as data type, constant variable, basic structure of program, method and array, etc. It does not involve too much object-oriented programming. The question we choose is how to develop a Cash Register System for a supermarket. It is carefully considered. Firstly, learners all have supermarket shopping experience and understand supermarket cash settlement, so this problem is easy to activate learners' old knowledge. Secondly, the problem of “Cash Register System” can be extended to the follow-up units (such as units for object-oriented, graphical user interface, multithread, network, and so on) to form the problem progression of the whole course. We decompose this problem into a problem progression, and create learning situations and learning objectives for the learners.

(1) Original problem

Problem Description: Selena runs a small supermarket which selling daily necessities, fruits and

vegetables. The supermarket is very busy, so she needs a cash register system to speed up the checkout and shorten the possible customer queue time. Selena knows every detail of the supermarket sale and is willing to pay for the hardware needed. You promised to help her develop the supermarket cash register.

(2) Problem progression

Problem 1:

Suppose there is a sample of the header of a ticket, which is as shown in Table 2.

Table 2 a Sample Of the Header of a Ticket

Name of store	Moonlight	Date	2019/05/27
Cash register	C01	Ticket number 00147947	
Cashier number	001	Type of trade	Retail

Now you need to write a program to print the ticket header in the console.

Problem 2:

Suppose there is a sample of the content of a ticket as shown in Table 3

Table 3 a Sample Of the Content of a Ticket

S/N	Code	Name	Quantity	Unit price	Amount
1	030147	Cucurbita pepo	0.94	6.98	
2	030055	Celery	0.764	2.57	
3	030133	cucumber	0.754	6.38	
Total quantity					
total amount					

Now you need to write a program to calculate the amount of each commodity, the total quantity of commodities and the total amount.

Problem 3:

In order to manage her clients, Selena plans to adopt membership system. According to the sales strategy, the supermarket sets some products as member products. Supermarket members have a discount on member products. Suppose that there is a sample of the content of a membership ticket as shown in Table 4.

Table 4 a Sample Of the Content of a Membership Ticket (Where t Means Yes, f Means No)

Member flag	T	Membership number	023807			
S/N	Code	Name	Quantity	Unit price	Discount	Amount
1	030147	Cucurbita pepo	0.94	6.98	0.8	
2	030055	Celery	0.764	2.57	0.85	
3	030133	cucumber	0.754	6.38	1	
Total quantity						
total amount						

Now you need to write a program to calculate the amount of each commodity, the total quantity of commodities and the total amount.

(3) Progressive problem sequence and knowledge point decomposition

Here we list three questions. These three questions form a series of questions from easy to difficult. The knowledge point decomposition of the first problem includes data type, constant, variable and input/output. The knowledge point decomposition of the second problem includes data type, constant, variable, input and output, arithmetic operation, sequence statement and cycle statement. The knowledge point decomposition of the third problem includes data type, constant, variable, input and output, arithmetic operation, sequence statement, cycle statement and selection statement. In fact, in addition to these three questions, we also designed a series of follow-up questions according to the course content.

(4) Systematic organization of knowledge points

The knowledge points decomposed by the problem progression do not cover all the knowledge points to be taught in the “Java programming foundation” unit, such as the basic composition of Java language and the basic structure of Java source program are not be covered. We need to add

the knowledge points that are not be covered to the knowledge point set, and then design the order of all knowledge points on the whole. We adjust the order of knowledge points so that they can meet the needs of systematization of subject knowledge and problem-solving progression at the same time. The order of knowledge points after reorganization is shown in Figure 3.

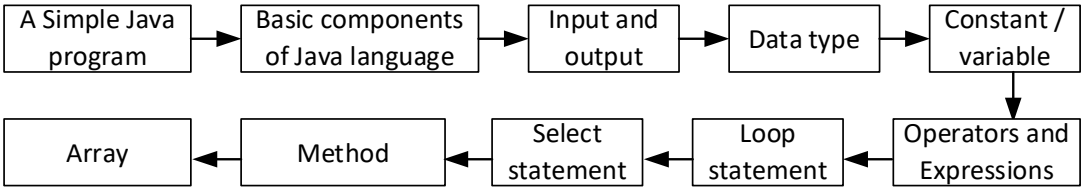

Figure 3 The Order of Knowledge Points of the "Java Programming Basics" Unit

(5) The application of question progression in teaching circle

The five-star teaching circle is divided into four stages: activating the old knowledge, demonstrating the new knowledge, applying the new knowledge, and integrating. These four phases can be implemented at the unit level or at the module level. Our strategy is that each problem in the problem progression corresponds to one or two modules. We refine the problem framework, elaborate the problem in natural language, and describe the algorithm in natural language. Such a problem refinement framework is used to activate old knowledge. In the demonstration stage, we explain the knowledge points, show the problem-solving process, and show the programming process. In the application of new knowledge stage, we design new application problems, and give limited guidance tips for problem solving, so that students can have a chance to solve problems themselves. In the integration stage, we did not give a unit summary directly, but let learners use mind map and anchor chart to complete the module summary by themselves. By making learners summarize and write their own learning notes, we can strengthen the systematic construction of learners' knowledge.

6. Conclusion

A good teaching design and an effective teaching organization are the basis of achieving e^3 teaching in online courses. When building online courses, teachers should not only focus on the technical presentation of discipline domain knowledge, but also integrate instructional design and organization into the whole process of online course construction and teaching. The teaching content, design and implementation of online courses should fully consider the basic laws of human cognitive psychology, and make use of teaching theories in order to achieve e^3 teaching of online courses.

We have studied the application of the First Principles of Instruction and the efficient learning methods compliant to cognitive psychology in online courses, and proposed an online course design framework based on the First Principles of Instruction. We have built an online course of Java programming using that framewok. Our teaching practice shows that the framework is effective in online course design and online teaching.

Based on this framework, we will introduce engineering management and quality management into online course development, so as to further improve the quality of online courses and the effectiveness of online teaching.

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